Renewable Energy Question #9: What is the long-term potential for more wind, solar, hydro, biomass, landfill gas, and other renewables sources in other locations to which Michigan is tied electrically?

Michigan is tied electrically to regions with substantial potential for renewable energy generation. Michigan is part of both the Midwest Independent System Operator (MISO) and the PJM Interconnection. MISO includes all or parts of Iowa, Illinois, Indiana, Kentucky, Minnesota, Missouri, Montana, North Dakota, South Dakota, Wisconsin, and Wyoming. PJM includes all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, North Carolina, New Jersey, Ohio, Pennsylvania, Virginia, and West Virginia. For the purpose of this assessment, we exclude Montana, South Dakota, Kentucky, and North Carolina; only a small part of these states is part of MISO or PJM territory.

The region to which Michigan is tied electrically has the technical potential to meet all of its electricity needs from renewable sources. Even after adjusting renewable energy potential based on economic and market limitations, the region still has the potential to use renewables to generate eight times total 2012 electricity demand—primarily with onshore wind, solar, and bioenergy.[1] And while not all of this technical potential can or should be tapped due to conflicting land use needs, cost considerations, transmission constraints, and other hurdles, Michigan still has the opportunity to draw on vast and diverse renewable energy resources within the state's surrounding region.

Below are the total technical potential, economic and market potential, and current generation of renewable energy from the 15 states to which Michigan is tied electrically:

(All values are in GWh)	**Estimated Technical Potential**	**Potential after economic and market limitations**	**2012 Electricity Generation**
Bioenergy	340,279	340,279	11,538
Geothermal	6,980,853	67,200	-
Hydropower	61,418[2]	65,558	14,918
Solar	69,665,897	323,014	522
Wind	56,251,192	9,430,339	48,723
Total	**133,299,639**	**10,226,390**	**75,701**
2012 Region Electricity Generation (15 states)			**1,273,313**

A more detailed breakdown of technical potential, economic and market potential, and current generation by technology and state:

[1] Note: Technical potential accounts for land-use and topographic constraints. Economic limitations include constraints related to projected technology costs and projected fuel costs. Market limitations include constraints related to policy, regulation, and investment.

[2] The hydropower numbers reported only include hydropower that has not yet been developed. Potential was added to the current generation to get total potential

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Delaware			
Bioenergy	1,147	1,147	107
Bioenergy - Landfill Gas		127	59
Geothermal	22,813	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	22,813	-	
Hydropower	31	5,074	-
Solar	274,518	3,718	30
Solar - Urban Utility-Scale Photovoltaic	14,856		
Solar - Rural Utility-Scale Photovoltaic	272,333		
Solar - Rooftop Photovoltaic	2,185		
Solar - Concentrating Solar	-	-	
Wind	60,676	22	-
Wind - Onshore Wind Power	22	22	
Wind - Offshore Wind Power	60,654	-	
Illinois			
Bioenergy	62,429	62,429	668
Bioenergy - Landfill Gas		2,041	1,036
Geothermal	676,056	15,053	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	676,056	15,053	
Hydropower	4,981	3,128	98
Solar	8,121,071	42,882	37
Solar - Urban Utility-Scale Photovoltaic	103,552		
Solar - Rural Utility-Scale Photovoltaic	8,090,985		
Solar - Rooftop Photovoltaic	30,086		
Solar - Concentrating Solar	-	-	
Wind	715,538	635,961	7,708
Wind - Onshore Wind Power	649,468	635,961	
Wind - Offshore Wind Power	66,070	-	
Indiana			
Bioenergy	35,047	35,047	347
Bioenergy - Landfill Gas		888	373
Geothermal	434,258	498	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	434,258	498	
Hydropower	2,850	3,703	456
Solar	4,893,337	24,002	-
Solar - Urban Utility-Scale Photovoltaic	98,815		
Solar - Rural Utility-Scale Photovoltaic	4,876,186		
Solar - Rooftop Photovoltaic	17,151		
Solar - Concentrating Solar	-	-	
Wind	377,770	370,235	2,231

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Wind - Onshore Wind Power	377,604	370,235	
Wind - Offshore Wind Power	166	-	
Iowa			
Bioenergy	70,019	70,019	162
Bioenergy - Landfill Gas		275	78
Geothermal	606,390	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	606,390	-	
Hydropower	3,639	2,461	821
Solar	7,002,805	12,855	-
Solar - Urban Utility-Scale Photovoltaic	27,092		
Solar - Rural Utility-Scale Photovoltaic	6,994,159		
Solar - Rooftop Photovoltaic	8,646		
Solar - Concentrating Solar	-	-	
Wind	1,723,588	1,683,397	13,945
Wind - Onshore Wind Power	1,723,588	1,683,397	
Wind - Offshore Wind Power	-	-	
Maryland			
Bioenergy	4,282	4,282	541
Bioenergy - Landfill Gas		393	162
Geothermal	86,649	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	86,649	-	
Hydropower	2,478	1,964	1,664
Solar	600,799	21,169	28
Solar - Urban Utility-Scale Photovoltaic	28,551		
Solar - Rural Utility-Scale Photovoltaic	585,949		
Solar - Rooftop Photovoltaic	14,850		
Solar - Concentrating Solar	-	-	
Wind	204,484	3,577	314
Wind - Onshore Wind Power	3,632	3,577	
Wind - Offshore Wind Power	200,852	-	
Minnesota			
Bioenergy	42,606	42,606	1,732
Bioenergy - Landfill Gas		372	183
Geothermal	369,785	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	369,785	-	
Hydropower	1,993	7,711	738
Solar	10,807,136	19,461	-
Solar - Urban Utility-Scale Photovoltaic	33,370		
Solar - Rural Utility-Scale Photovoltaic	10,792,814		
Solar - Rooftop Photovoltaic	14,322		
Solar - Concentrating Solar	-	-	
Wind	1,528,980	1,392,480	7,529

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Wind - Onshore Wind Power	1,428,525	1,392,480	
Wind - Offshore Wind Power	100,455	-	
Missouri			
Bioenergy	33,893	33,893	-
Bioenergy - Landfill Gas		535	196
Geothermal	835,445	112	
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	835,445	112	
Hydropower	7,919	552	721
Solar	5,351,429	24,695	-
Solar - Urban Utility-Scale Photovoltaic	30,549		
Solar - Rural Utility-Scale Photovoltaic	5,335,269		
Solar - Rooftop Photovoltaic	16,160		
Solar - Concentrating Solar	-	-	
Wind	689,519	679,482	1,245
Wind - Onshore Wind Power	689,519	679,482	
Wind - Offshore Wind Power	-	-	
New Jersey			
Bioenergy	1,364	1,364	922
Bioenergy - Landfill Gas		710	588
Geothermal	35,230	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	35,230	-	
Hydropower	549	2,827	-
Solar	455,542	21,891	349
Solar - Urban Utility-Scale Photovoltaic	44,307		
Solar - Rural Utility-Scale Photovoltaic	439,774		
Solar - Rooftop Photovoltaic	15,768		
Solar - Concentrating Solar	-	-	
Wind	430,125	317	13
Wind - Onshore Wind Power	317	317	
Wind - Offshore Wind Power	429,808	-	
North Dakota			
Bioenergy	14,294	14,294	7
Bioenergy - Landfill Gas		17	6
Geothermal	820,226	1,247	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	820,226	1,247	
Hydropower	2,824	3,175	2,477
Solar	9,774,415	3,236	-
Solar - Urban Utility-Scale Photovoltaic	4,871		
Solar - Rural Utility-Scale Photovoltaic	9,736,448		
Solar - Rooftop Photovoltaic	1,917		
Solar - Concentrating Solar	36,050	-	
Wind	2,537,825	2,487,758	5,316

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Wind - Onshore Wind Power	2,537,825	2,487,758	
Wind - Offshore Wind Power	-	-	
Ohio			
Bioenergy	21,547	21,547	684
Bioenergy - Landfill Gas		1,168	341
Geothermal	495,922	91	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	495,922	91	
Hydropower	3,427	10,661	381
Solar	3,656,246	45,141	38
Solar - Urban Utility-Scale Photovoltaic	86,496		
Solar - Rural Utility-Scale Photovoltaic	3,626,182		
Solar - Rooftop Photovoltaic	30,064		
Solar - Concentrating Solar	-	-	
Wind	299,704	130,199	988
Wind - Onshore Wind Power	129,143	130,199	
Wind - Offshore Wind Power	170,561	-	
Pennsylvania			
Bioenergy	11,592	11,592	2,426
Bioenergy - Landfill Gas		1,623	1,017
Geothermal	327,341	126	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	327,341	126	
Hydropower	10,681	4,669	2,313
Solar	575,571	37,745	40
Solar - Urban Utility-Scale Photovoltaic	56,162		
Solar - Rural Utility-Scale Photovoltaic	553,356		
Solar - Rooftop Photovoltaic	22,215		
Solar - Concentrating Solar	-	-	
Wind	31,802	8,169	2,208
Wind - Onshore Wind Power	8,231	8,169	
Wind - Offshore Wind Power	23,571	-	
Virginia			
Bioenergy	16,518	16,518	2,255
Bioenergy - Landfill Gas		708	608
Geothermal	290,737	15	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	290,737	15	
Hydropower	4,664	5,567	1,007
Solar	1,904,734	29,831	-
Solar - Urban Utility-Scale Photovoltaic	27,451		
Solar - Rural Utility-Scale Photovoltaic	1,882,467		
Solar - Rooftop Photovoltaic	22,267		
Solar - Concentrating Solar	-	-	
Wind	365,643	162,770	-

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Wind - Onshore Wind Power	4,589	4,534	
Wind - Offshore Wind Power	361,054	158,236	
West Virginia			
Bioenergy	6,426	6,426	-
Bioenergy - Landfill Gas		161	13
Geothermal	261,376	1,724	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	261,376	1,724	
Hydropower	5,735	4,289	1,327
Solar	56,914	9,944	-
Solar - Urban Utility-Scale Photovoltaic	3,024		
Solar - Rural Utility-Scale Photovoltaic	52,694		
Solar - Rooftop Photovoltaic	4,220		
Solar - Concentrating Solar	-	-	
Wind	4,952	4,881	1,286
Wind - Onshore Wind Power	4,952	4,881	
Wind - Offshore Wind Power	-	-	
Wisconsin			
Bioenergy	18,408	18,408	1,687
Bioenergy - Landfill Gas		768	635
Geothermal	647,173	-	-
Geothermal - Hydrothermal Power	-	-	
Geothermal - Enhanced Geothermal Systems & Co-Produced	647,173	-	
Hydropower	4,307	5,336	2,020
Solar	5,056,198	22,466	-
Solar - Urban Utility-Scale Photovoltaic	54,939		
Solar - Rural Utility-Scale Photovoltaic	5,042,259		
Solar - Rooftop Photovoltaic	13,939		
Solar - Concentrating Solar	-	-	
Wind	573,021	252,809	1,546
Wind - Onshore Wind Power	255,266	252,809	
Wind - Offshore Wind Power	317,755	-	
Wyoming			
Bioenergy	707	707	-
Bioenergy - Landfill Gas		70	-
Geothermal	1,071,452	48,334	-
Geothermal - Hydrothermal Power	1,373	53	
Geothermal - Enhanced Geothermal Systems & Co-Produced	1,070,079	47,115	
Hydropower	5,340	4,441	895
Solar	11,135,182	3,978	-
Solar - Urban Utility-Scale Photovoltaic	7,232		
Solar - Rural Utility-Scale Photovoltaic	5,727,224		
Solar - Rooftop Photovoltaic	1,551		
Solar - Concentrating Solar	5,406,407	-	
Wind	1,653,857	1,618,282	4,394

	Estimated Technical Potential	Potential after economic and market limitations	2012 Electricity Generation
Wind - Onshore Wind Power	1,653,857	1,618,282	
Wind - Offshore Wind Power	-	-	

Resources:

1) NREL - U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis. Online at http://www.nrel.gov/docs/fy12osti/51946.pdf.

2) EIA Electricity Production Monthly. Online at http://www.eia.gov/electricity/.

3) Walsh, M. 2008. *U.S. Cellulosic Biomass Feedstock Supplies and Distribution*. June 24. Oak Ridge, TN: M&E Biomass. (Biomass Potential at $90/dry ton). Online at http://ageconsearch.umn.edu/bitstream/7625/2/U.S.%20Biomass%20Supplies.pdf; accessed April 22, 2013.

4) Petty, S. and G. Porro. 2007. "Updated U.S. Geothermal Supply Characterization, "National Renewable Energy Laboratory Presented at the 32nd Workshop on Geothermal Reservoir Engineering Stanford, California January 22–24, 2007 NREL/CP-640-41073. March 2007. http://www.nrel.gov/docs/fy07osti/41073.pdf

5) Table B-1. DOE. EERE. "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants," January 2006 DOE-ID-11263. Online at http://hydropower.inl.gov/resourceassessment/pdfs/main_report_appendix_a_final.pdf.

6) Chaudhari, M., L. Frantzis, T. Hoff. September 2004. Navigant Consulting. *PV Grid Connected Market Potential under a Cost Breakthrough Scenario*. Navigant Consulting, Cambridge, MA. Online at http://www.ef.org/documents/EF-Final-Final2.pdf.

7) U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind Powering America Program. 2010. Wind Maps and Wind Resource Potential Estimates. February. Available online at: http://www.windpoweringamerica.gov/wind_maps.asp#potential.